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THE ELUSIVE CONTRIBUTION OF ICT TO PRODUCTIVITY GROWTH IN NEW ZEALAND: EVIDENCE FROM AN EXTENDED INDUSTRY-LEVEL GROWTH ACCOUNTING MODEL

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ABSTRACT

This paper explores the impacts of Information and Communication Technologies (ICT) on economic growth in New Zealand. Using an extended industry-level growth accounting model to analyse the proximate sources of growth in per capita output, we focus on differences in total factor productivity (TFP) growth and its sub-components, as well as other major components of labour productivity (LP) growth, that emerge between 'more ICT intensive' and 'less ICT intensive' industries. Employing, alternatively, gross output and net output data, we find great differences and distinct patterns in the growth contributions of the two types of industries. However, the quest to find evidence of positive ICT impacts is still somewhat elusive. Although TFP growth of more ICT intensive industries has steadily increased in importance over time, 'pure' or within-industry productivity effects are smaller than structural change effect, and LP growth has only accelerated in recent years.

1. INTRODUCTION

New Zealand (NZ)'s GDP per capita growth has improved since the early 1990s. In the eleven years to 2002, it was around 2.25 percent compared to 1.75 percent for the OECD as a whole (Treasury, 2004, p. 4). The economic reforms that began in 1984 have played an important, though still somewhat controversial, contributing role.[1] However, in terms of the level of GDP per capita, NZ is currently still only ranked 20th in the OECD (MED/Treasury, 2005). In this context, concerns have been raised about NZ's weak productivity performance. Compared to most other OECD countries, labour productivity (LP) growth has been poor (ibid.; OECD, 2003, 2005). Raising it is seen as the main economic challenge facing the country (OECD, 2005). A number of studies suggest that relatively low growth rates of human capital stocks, weak capital deepening and low total factor productivity (TFP) growth may have been the main factors behind the low rate of LP growth in NZ (see, for example, Treasury, 2004; McLellan, 2004; Oxley, 2004; Parham and Roberts, 2004; MED/Treasury, 2005).

This paper contributes to this debate by analysing the proximate sources of per capita output growth for the period 1988-2003, and relevant sub-periods, using an extended industry-level growth accounting model, and focussing on the differences between 'more ICT intensive' and 'less ICT intensive' industries. It complements an earlier paper (i.e. Engelbrecht and Xayavong, 2006) that describes the derivation of the

[1] See, for example, Treasury (2004). For an introduction to the economic reforms in NZ, see Dalziel and Lattimore (2004), and the references cited therein. Engelbrecht (2000) specifically focuses on questions concerning the development of a knowledge economy in NZ.

distinction between the two types of industries using NZ-specific data and reports results from LP growth difference-in-difference regressions. The earlier findings were supportive of the view that LP growth of more ICT intensive industries has improved over time relative to that of other industries, even though overall LP growth has been weak. This paper provides further suggestive evidence, derived using a different methodology and a closer alignment of sub-periods to business cycles, supporting the conclusion about the differential productivity impacts of more ICT intensive industries in NZ. However, for LP growth they seem to have occurred later than suggested by Engelbrecht and Xayavong (2006), i.e. only from the late 1990s and not from the early 1990s onwards. In contrast, TFP growth of more ICT intensive industries, which we did not analyse in the earlier paper, has increased more steadily over time, although it has been mostly due to structural change effects instead of within-industry productivity gains.

The paper includes little methodological novelty. However, aspects distinguishing it from many other growth accounting studies are the focus on a gross output based approach in preference to a net output based approach, and the application of Nordhaus' (2002a,b) decomposition of TFP to more ICT intensive versus less ICT intensive industries. We argue in favour of the country-specific approach adopted here for deriving the industry split, instead of using a 'one-size-fits all' definition. We feel that these issues need to be given more attention in the literature on industry-level ICT productivity impacts.

The paper is organized as follows. Section 2 introduces the methodology. Data sources and measurement issues are discussed in Section 3. Industry-level LP growth rates are discussed in Section 4. Section 5 presents our results for the proximate sources of output and productivity growth in NZ. This is followed by a brief summary and concluding comments (Section 6), and two appendices.

2. AN EXTENDED INDUSTRY-LEVEL GROWTH ACCOUNTING MODEL

By now a number of industry-level growth accounting studies, mostly for the U.S. but increasingly also for European Union countries, have focussed on ICT (goods and/or services) producing industries versus other industries (for example Oliner and Sichel, 2002; Nordhaus, 2002a; Jorgenson *et al.*, 2003), or distinguish between ICT (goods and/or services) producing industries, intensively ICT using industries and other industries (for example Ark *et al.*, 2002; Stiroh, 2002; Inklaar *et al.*, 2003; Daveri, 2003; OECD, 2004; Ark, 2005). These studies also usually separate ICT from non-ICT capital stocks. Unfortunately, the NZ data are more limited than for most other developed countries. They do not allow us to split ICT producing from intensively ICT using industries. However, the former are small in NZ. Moreover, we do not have separate ICT capital stock estimates available. Therefore, although the neo-classical growth accounting methodology employed in this paper is tailored to focus on the major currently debated productivity issues in NZ (the relationship between LP growth and TFP growth, and the main factors driving both), the available data limit the way per capita output growth can be decomposed into its proximate sources.[2]

[2] In particular, the level of industry disaggregation required to distinguish between more ICT intensive and less ICT intensive industries means that LP can only be measured in terms of output per full time equivalent employee, not in terms of ouput per hour worked (which is usually the preferred measure).

The growth accounting model is build up in several steps. Firstly, the change in annual average per capita output growth is decomposed into labour utilisation and LP growth. In our case, these two components can be written as follows:

$$\Delta \ln(\mathrm{Y}/\mathrm{P})_{\mathrm{t}} = \sum_{\mathrm{i}} \bar{\sigma}_{\mathrm{i,t}} \Delta \ln(\mathrm{E}/\mathrm{P})_{\mathrm{i,t}} + \sum_{\mathrm{i}} \bar{\sigma}_{\mathrm{i,t}} \Delta \ln(\mathrm{Y}/\mathrm{E})_{\mathrm{i,t}} \tag{1}$$

where i = 1,…, 29 indexes industries and t = 1,…, 15 indexes the annual observations over the period 1988-2003. Y represents gross output, E is the number of full time equivalent (FTE) employees, P is total population, $\bar{\sigma}_{\mathrm{i,t}}$ is the two-year average share of nominal output of industry i in total nominal output. The first term on the right hand side of Equation (1) is the weighted annual-average labour utilisation; the second term is LP growth.

Secondly, LP growth is further decomposed into four components as follows:[3]

$$\begin{aligned} \Delta \ln(Y/E)_t = \sum_i \bar{\sigma}_{i,t} \Delta \ln(Y/E)_{i,t} &= \sum_i \bar{\sigma}_{i,t} \bar{\alpha}_{i,t} \Delta \ln(K/E)_{i,t} \\ &+ \sum_i \bar{\sigma}_{i,t} \bar{\beta}_{i,t} \Delta \ln(L/E)_{i,t} \\ &+ \sum_i \bar{\sigma}_{i,t} \bar{\gamma}_{i,t} \Delta \ln(M/E)_{i,t} \\ &+ \sum_i \bar{\sigma}_{i,t} \Delta \ln(A)_{i,t} \end{aligned} \tag{2}$$

However, over the period analysed in this paper the average number of hours worked per person employed in NZ has fluctuated in a fairly narrow range, i.e. between 1,800 and 1,850, without showing a clear trend of people working either more or fewer hours (MED/Treasury, 2005, p. 30).

[3] See Appendix 1 for details on how equation (2) is derived.

where *K, L* and *M* respectively represent (physical) capital input, labour input and intermediate input, *A* is total factor productivity, and $\overline{\alpha}_{\mathrm{i,t}}, \overline{\beta}_{\mathrm{i,t}}$ and $\overline{\gamma}_{\mathrm{i,t}}$ are the two-year average shares of nominal capital input, labour input, and intermediate input, respectively. The first term on the right hand side of Equation (2) is weighted annual average capital deepening, which measures the increase in capital services per employee. The second term is the weighted annual average growth in labour quality, which measures the substitution towards workers with higher marginal products. The third term measures the annual average growth in intermediate inputs or 'intermediate input deepening' (Jorgenson *et al.*, 2003). The fourth term is weighted annual average TFP growth, i.e. the 'residual' that measures the impacts of technical change and other factors like scale economies, spillovers, and measurement errors that raise output growth beyond the measured contribution of inputs (see Barro and Sala-i-Martin, 2004, chapter 10) .

A comment is required on the inclusion of intermediate inputs. Like in Engelbrecht and Xayavong (2006), we prefer gross output based, instead of net output (i.e. value added) based, LP and TFP growth measures. We regard this as an advantage of this study compared to many other ICT growth accounting studies. Stiroh (2002, p. 1562) has pointed out that the existence of value-added functions is often rejected in the literature. Their use might, therefore, lead to biased estimates and incorrect inferences. The inclusion of intermediate inputs should result in a better apportioning of the growth contributions of other factors. Jorgenson and Stiroh (2000) and Jorgenson *et al.* (2003) comment that inclusion of intermediate inputs allows aggregate productivity gains to be more correctly allocated among industries. Cobbold (2003) argues that value added based productivity measures may distort industry productivity growth rates over time, and that they appear to distort inter-industry productivity growth comparisons. However, it should be noted that both gross output and net output based productivity measures have advantages and disadvantages (see OECD, 2001). Therefore, for comparative purposes we also perform our growth accounting exercise using the latter. They will be commented on briefly where appropriate.

In order to closer examine the factors responsible for TFP growth, we further use an extended version of the decomposition method developed by Nordhaus (2002a,b). In a third step TFP growth is decomposed into four components as follows:

$$\begin{aligned}\Delta \ln(A)_t = \sum_i \bar{\sigma}_{i,t} \Delta \ln(A)_{i,t} &= \sum_i \bar{\sigma}_{i,0} \Delta \ln(A)_{i,t} \\ &+ \sum_i \left[\bar{\sigma}_{i,t} - \bar{\sigma}_{i,0}\right] \Delta \ln(A)_{i,t} \\ &+ \sum_i \left[\bar{\sigma}_{i,t} - \bar{w}_{i,t}\right] \Delta \ln(S)_{i,t} \\ &+ \sum_i \left[\bar{z}_{i,t} - \bar{\sigma}_{i,t}\right] \Delta \ln(Y)_{i,t}\end{aligned} \tag{3}$$

where $\bar{w}_{i,t} = \bar{\alpha}_{i,t} + \bar{\beta}_{i,t} + \bar{\gamma}_{i,t}$ represents the two-year average share of inputs of industry i in total composite inputs, $z_{i,t}$ is the two-year average share of real output of industry i in total real output, $\Delta\ln(S_{i,t})$ is the growth of inputs, and $\Delta\ln(Y_{i,t})$ is the growth of outputs. The first term on the right hand side of Equation (3) is the fixed-weighted average of the TFP growth rates of different industries. It measures the ‘pure’ productivity effect in the absence of changing shares of nominal output among industries over time. The second term is the “Baumol effect”. It measures the proportion of overall productivity growth that is due to the changing shares of nominal output among industries over time (i.e. the difference between current and base-year nominal output weights). It is usually interpreted as capturing the effect of *low productivity growth* industries having rising nominal output shares. The third term, called the "Denison effect", accounts for *productivity level* effects due to changes in industry structure, i.e. the interacted changes between growth of inputs and the shares of output and inputs over time. In other words, this term captures the productivity gains from reallocating resources from low to high productivity industries (Nordhaus, 2002a, p. 215). The fourth term is a fixed-weight drift term, which tends to be close to zero if, like in case of our data, chain indexes are used to measure output growth.

Besides pure productivity effects we expect a large proportion of TFP growth in NZ to be captured by the Baumol and Denison effects, because there has been a marked change in NZ's industrial structure since the start of the economic reforms in the mid 1980s (see, for example, Buckle *et al.*, 2001). Market deregulation and liberalization will have affected the real prices of inputs and outputs, leading to reallocation of resources within and between industries.

In a fourth step we substitute Equations (2) and (3) into Equation (1). This yields:

$$\begin{aligned}\Delta \ln(Y/P)_t &= \sum_i \overline{\sigma}_{i,t} \Delta \ln(E/P)_{i,t} + \sum_i \overline{\sigma}_{i,t} \overline{\alpha}_{i,t} \Delta \ln(K/E)_{i,t} \\ &+ \sum_i \overline{\sigma}_{i,t} \overline{\beta}_{i,t} \Delta \ln(L/E)_{i,t} + \sum_i \overline{\sigma}_{i,t} \overline{\gamma}_{i,t} \Delta \ln(M/E)_{i,t} \\ &+ \sum_i \overline{\sigma}_{i,0} \Delta \ln(A)_{i,t} + \sum_i \left[\overline{\sigma}_{i,t} - \overline{\sigma}_{i,0}\right] \Delta \ln(A)_{i,t} \\ &+ \sum_i \left[\overline{\sigma}_{i,t} - \overline{w}_{i,t}\right] \Delta \ln(S)_{i,t} + \sum_i \left[\overline{z}_{i,t} - \overline{\sigma}_{i,t}\right] \Delta \ln(X)_{i,t} \qquad (4)\end{aligned}$$

The interpretation of Equation (4) is that per capita output growth is determined by changes in labour utilization, capital deepening, labour quality, intermediate input deepening, technology (i.e. the pure productivity effect), as well as the impacts of structural changes in the economy (the Baumol and Denison effects).

To obtain our final growth accounting formula, we further divide each term in Equation (4) into two, i.e. into contributions from more ICT intensive industries and less ICT intensive industries (Step 5). In this way we are able to quantify the relationships between relative ICT intensity and the components of the growth accounting decomposition.

It should be noted that the methodology adopted in this paper has well-known limitations that have to be taken into account when interpreting the results. The key assumptions underlying growth accounting are those of neo-classical economics: Markets are assumed to be perfectly competitive and production functions have constant returns to scale. The former is not especially realistic while the latter is likely to be violated to varying degrees due to the presence of spillover effects and increasing returns. Thus, the values obtained for the right hand side components of Equation (4) may deviate from their true values. Obtaining the latter may require the use of sophisticated econometric techniques. However, Barro and Sala-i-Martin (2004, Ch.10) demonstrate that various spillover and other effects are captured by TFP growth.[4] They argue that growth accounting exercises, despite their shortcomings, are

[4] Moreover, the regression approach also has a number of well-known disadvantages which make many analysts prefer the use of growth accounting approaches (see Barro and Sala-i-Martin, 2004, pp. 441/2).

still useful in that they can provide clues for further analysis and theory building. However, they do not provide a theory of growth. In fact, they are usually compatible with very different visions of growth (ibid.). In the case of NZ this could even be regarded as an advantage, because the country's growth experience does not seem to conform with any of the major growth theories currently in vogue.[5]

A related limitation of the growth accounting methodology more specifically due to ICT and other 'general purpose technologies' is the fact that technological change does not necessarily translate into TFP growth, nor is TFP growth necessarily caused by technological change (Schreyer, 2001, pp. 111-3; Lipsey and Carlaw, 2004). In a sense, our analysis is only able to provide snapshots of some of the outcomes of complex inter-related dynamic growth processes which in turn are determined by the underlying ultimate or deep determinants of growth.

3. DATA SOURCES AND MEASUREMENT ISSUES

Most of the data used in this paper are drawn from Statistics New Zealand's national accounts. Data on the values and volumes series in production and income accounts were available for the period 1988-2001. Those for 2002 and 2003 had to be constructed using the same technique as that employed in Engelbrecht and Xayavong

[5] Engelbrecht and McLellan (2002) test the applicability of various endogenous growth models as well as exogenous growth and find that none seems to be able to properly explain the NZ growth experience.

(2006).[6] All volumes series are measured in 1995/96 prices. Industry real gross output is used for output, a real series of productive capital stocks is used for capital input. Numbers of FTE employees were taken from Engelbrecht and Xayavong (2004, Table A.2, p. 32/3) and used for labour input. Industry-level labour quality is measured by the difference between growth rates of labour compensation and FTE employment. This method is consistent with the concept of the labour-income-based measure of human capital, which is commonly used as a simple proxy for human capital (Mulligan and Sala-i-Martin, 1997).

Regarding the measurement of industry factor input shares, the capital shares are set equal to the ratio of the costs of capital investment to nominal gross output. The costs of capital investment are obtained by multiplying capital prices by capital inputs. The capital prices (the rates of returns on capital investment) are constructed by taking the ratio of operating surplus to net capital stock. Labour (intermediate input) shares are set equal to the ratio of the values of labour compensation (intermediate input value) to nominal gross output. It should be noted that the 1993 System of National Accounts treats labour income of the self-employed as business benefits. As a consequence this labour income is included in the operating surplus series instead of the labour compensation series. Thus, labour (capital) shares are likely to be somewhat under

[6] See the discussion paper version of that paper (Engelbrecht and Xayavong, 2004, Appendix A) for more detailed information on data construction and sources than is provided here. One difference is that for this study, official production and income accounts data were available for 2000 and 2001, whereas they had to be constructed for the earlier study. Also note that capital services and net capital stocks were sourced from Statistics NZ. The former were used as proxy for capital inputs, the latter were used to estimate the price, i.e. cost, of capital.

(over) estimated. Due to lack of appropriate data at the two-digit industry level, we do not adjust these series.[7]

As explained in detail in Engelbrecht and Xayavong (2004, 2006), the split of industries into more ICT intensive and less ICT intensive is based on a NZ specific industry-level ICT intensity index, calculated from input-output data. This index measures the percentage of ICT inputs in total intermediate inputs. If for a particular industry this percentage is greater (smaller) than the median for all industries, the industry is designated as more (less) ICT intensive. This procedure results in what we call 'Industry Classification A'. However, three industries, i.e. 'Agriculture', 'Textiles and Apparel Manufacturing' and 'Furniture and Other Manufacturing' have an ICT intensity just below the median. It should be noted that other authors usually designate sub-sectors of the last two as ICT intensive in other countries. Moreover, NZ agriculture is known to be more R&D and technology intensive compared to other OECD countries. We therefore include these three sectors as more ICT intensive in an alternative, but somewhat less precise, 'Industry Classification B', which we employ as a simple sensitivity analysis of our industry split.

One referee questioned our use of a NZ-specific industry split instead of using the OECD definition of the ICT sector to insure international comparability of our results. Our response is that the OECD definition focuses on ICT producing industries, neglecting most of the large ICT intensive services industries included in our 'more

[7] However, the distortion is likely to be small. McLellan (private communication) provided data suggesting that Black et al. (2003) estimated sole proprietor income to only add about 2 percent to total labour compensation.

ICT intensive' industry group.[8] We see a place for both types of studies, but, like Stiroh (2002) and van Ark et al. (2002), we prefer to let the data determine which industries to classify as either more ICT intensive or less ICT intensive in a particular country. In our opinion this data-driven approach has a better chance of capturing the diversity of industry-level experiences of economies with respect to ICT intensity. In the case of NZ, we even found it necessary to include agriculture, a key feature of the economy compared to other OECD countries, in 'industry classification B'. By comparison, using the OECD definition would impose a 'one-size-fits-all' straight jacket approach. However, we do provide a comparison of our industry split with that of Stiroh (2002) and van Ark et al. (2002) (see Appendix Table A1).

We report our main results for three sub-periods (1988-1992, 1992-1999, and 1999-2003) as well as for the whole 1988-2003 period. The 1992-1999 period covers a complete business cycle (trough to trough). The first sub-period experienced a downturn in GDP growth, the third period an upswing (see Dalziel and Lattimore, 2004, p. 114). It is important to take account of the business cycle in growth accounting as LP growth and TFP growth are often pro-cyclical, and cutting across business cycle phases can lead to distorted results and interpretations. This point is neglected in many of the comparative ICT productivity studies that focus on common time periods across countries.

4. INDUSTRY-LEVEL BASED LABOUR PRODUCTIVITY GROWTH RATES

[8] See OECD (2002). Table A.1 on page 83 of that publication provides a concordance table between the OECD definition of the ICT sector and the industry classification used in NZ.

Before presenting our main results, we provide a description of the LP growth performance at the industry level. Engelbrecht and Xayavong (2004, 2006) treat 1993-2003 as a single period. However, Table 1 indicates that most of the increase in the LP growth rate of more ICT intensive industries as a whole occurred only during the economic upswing from 1999 onwards, especially when industry classification A is used (see both the simple means and the output share weighted means). Another noteworthy point is that the drastic decline in LP growth of less ICT intensive industries from the first to the second period, and the drastic increase from the second to the third period, is much reduced when output share weighted means are used instead of simple means.

As already noted in Engelbrecht and Xayavong (ibid.), there are striking disparities in LP growth rates between individual industries, though they are not unusual by international standards. In terms of more ICT intensive industries, the increases seem to be concentrated in some of the more ICT intensive services industries (Communication Services, Wholesale and Retail Trade, Finance and Insurance, Transport and Storage) as well as the more ICT intensive manufacturing industries Machinery and Equipment Manufacturing.[9] This pattern of industry-level LP performance of more ICT intensive industries from 1999 onwards resembles that of the U.S. (see, for example, Inklaar *et al.*, 2003), and is different from that observed for the period 1993-2003 in Engelbrecht and Xayavong (2004, 2006). Taking proper

[9] Also, all of these industries, except Communication Services, experienced a decline in their average output shares from 1992-1999 to 1999-2003 (see Table A2 for the output share weights used to derive the weighted means). Overall, however, the output share for more ICT intensive industries has changed very little over time.

account of the business cycle, as is done in this paper, matters for our results, though one has to be careful not to read too much into our industry level data given their shortcomings.

[put Table 1 about here]

Net output based LP growth rates are similar to those shown in Table 1, but some important differences also emerge (see Table 2). In particular, using the net output approach seems to miss the pro-cyclical LP growth acceleration during the economic upturn from the late 1990s onwards. This applies to both weighted and simple means, as well as to the use of both industry classifications. However, for our preferred measure (i.e. weighted means, industry classification A), the productivity growth differential in favour of more ICT intensive industries during the 1999-2003 period (i.e. 0.84 versus 0.41) is even larger than in the case of gross output based LP growth rates.

[put Table 2 about here]

5. THE PROXIMATE SOURCES OF OUTPUT AND PRODUCTIVITY GROWTH IN NEW ZEALAND

Table 3 reports the main results of our growth accounting exercise. The first decomposition of growth of per capita output into labour utilisation and LP growth reveals that the largest contribution was made by the latter. Secondly, the further decomposition of LP growth into its four components indicates that the contribution of capital deepening has declined greatly over time. This increasing 'capital shallowness' of the NZ economy has attracted the attention of a number of analysts, without having, as yet, been fully explained.[10] Further, the contribution of labour quality has been fairly steady over time but small.[11] Intermediate input deepening made a large contribution to LP growth during the first two periods.[12] The contribution of TFP growth was negative in the first period, but improved greatly over time, both from the first to the second period, and from the second to the third period. In fact, it increased to such an extent that during 1999-2003 it accounted for the largest contribution to LP growth.

Looking at the results for more ICT intensive versus less ICT intensive industries, *great differences and clear patterns emerge.* First, capital shallowness is worse for more ICT intensive industries. The finding is seemingly in line with those of others reporting that NZ's rate of investment in ICT has been low compared to Australia's and that of other OECD countries (Parham and Roberts, 2004; MED/Treasury, 2005; OECD, 2005). However, as mentioned before, data issues loom large. Moreover, in

[10] Hall and Scobie (2005) explore differences in capital intensity between NZ and Australia. The greater fall in relative labour costs and hence the share of labour income in NZ, due to more extensive labour market liberalization in the early 1990s, is one possible factor, but many questions, for example about the proper scope of the capital measure, remain. In short, it is possible that NZ's capital shallowness is due to data shortcomings, i.e. it might be more apparent than real. Only the availability of improved capital stock data will enable analysts to shed more light on this issue.

[11] This has also been observed by others (see, e.g., OECD, 2003).

[12] Similarly, Jorgenson and Stiroh (2000) and Jorgenson *et al.* (2003) find a large contribution of intermediate input deepening to output growth and LP growth in the U.S.

general one might expect more ICT intensive industries to have a lower capital intensity: many of them are services industries which are likely to invest less in non-ICT capital inputs than manufacturing industries. Without having industry-level data for both ICT and non ICT capital stocks we cannot properly assess this issue. Secondly, by far the larger contribution of labour quality to overall LP growth since 1992 has been due to more ICT intensive industries, indicating their greater use of skilled labour. However, it was still a very small contribution to overall LP growth in each period. Thirdly, gains in LP growth from intermediate input deepening came mostly from less ICT intensive industries. Fourthly, the contribution of less ICT intensive industries to TFP growth was negative in each of the sub-periods. In contrast, it increased greatly over time for more ICT intensive industries. During 1999-2003, TFP growth in more ICT intensive industries accounted for the largest positive contribution to LP growth not only in these industries, but in overall LP growth and growth of per capita output (1% out of 2.14% and 2.82%, respectively). This finding is interesting, as so far similar effects only seem to have been observed for the U.S. and Australia.[13] To sum up, the differences between more ICT intensive and less ICT intensive industries are quite pronounced and seem to vindicate our approach of distinguishing between the two in the NZ context.

[put Table 3 about here]

There is a question mark over what the large contribution of TFP growth to overall economic growth in recent years really means. The decomposition of TFP growth into

[13] Pilat and Wölfl (2004) report that the U.S. and Australia are almost the only OECD countries for which there is evidence, at the sectoral level, that ICT *use* has increased LP growth and TFP growth.

its four components reveals a clear pattern in terms of the relative contributions of the two types of industries. The superior TFP performance of more ICT intensive industries is mainly due to the Denison effect, and to a lesser extent the pure productivity effect. By contrast, the negative TFP growth contribution of less ICT intensive industries seems almost entirely due to a negative Dension effect. Most analysts emphasize the importance of the pure productivity effect over the structural changes captured by the Dension effect (see, for example, Stiroh, 2002). The findings for NZ might therefore be seen as cause for concern. To raise living standards over time, it seems necessary to increase TFP growth within industries, not just to relocate resources from low to high productivity industries. The OECD (2003, p. 96) has confirmed this for a number of member countries, arguing that productivity growth during the 1990s was mostly due to within industry performance, not structural changes. NZ seems to be one of the OECD countries that did not display this trend. The potential policy implications of the predominance of structural change effects are beyond the scope of this paper but warrant further research.[14]

The remaining two components did not contribute to TFP growth. The fixed weight drift term is close to zero as expected. The absence of the Baumol effect for both types

[14] Suffice it to say there is also some more mixed evidence on the relative importance of pure productivity versus structural change effects. Daveri (2003, Table 5) finds that when assessing the growth contribution of ICT using industries, the latter effect is stronger than the former effect for large European countries and Japan, but the opposite holds for the U.S. When he analyses the combined growth contributions of ICT producing and ICT using industries, the structural change effect is still stronger than the pure productivity effect for the U.K. and Canada. If Daveri's analysis is correct, NZ's experience can be seen as similar to that of other English speaking countries (excluding the U.S.), making it appear less of an outlier.

of industries might seem surprising at first. However, Nordhaus (2002a) finds a similarly almost non-existent Baumol effect for the U.S., especially since the late 1980s.[15]

The findings reported in Table 3 have been subjected to a number of sensitivity analyses. First, growth accounting estimates obtained using industry classification B are very similar to those reported in Table 2 (they are reported in Engelbrecht and Xayavong, 2005, Table A.3, p. 15). Secondly, we also performed our analysis using net output based productivity measures (see Table 4)[16]. In that case, there is hardly any increase in overall LP growth from 1992-99 to 1999-2003, and a decline in TFP growth. Instead of pro-cyclical TFP growth, it is now anti-cyclical. TFP growth of more ICT intensive industries happens mostly from the first to the second period, not from the second to the third period. This also applies to the increase in the Denison and pure productivity effects for more ICT intensive industries. In short, these findings seem less plausible than those obtained from the analysis based on gross output based productivity measures.

[put Table 4 about here]

Thirdly, a referee queried the reliability of the results obtained for the last period, which are crucial for our two main findings, i.e. that there is a cyclical pattern in the

[15] However, it should be noted that apart from the general features of the productivity decomposition, Nordhaus' (2002a) methodology is quite different from ours, i.e. he uses a net output based approach that neglects capital (and therefore cannot analyse TFP growth).

[16] The estimates obtained using industry classification B are reported in Engelbrecht and Xayavong (2005, Table A.5, p. 17).

development of productivity, and that ICT intensive industries performed appreciably better in terms of productivity growth than other industries during that period. We had to construct some of the data for the years 2002 and 2003, and this might have influenced the estimates. Following the referee's suggestion, we dropped the last two years of data and recalculated our estimates for a shortened third period (1999-2001)(see Table 5).

[put Table 5 about here]

The new estimates indicate that some of our previous conclusions, in particular those derived from estimates obtained using net output data, are indeed sensitive to this change. The LP growth acceleration from the second to the third period is now larger and sizable for both types of industries, and there is no decline in TFP growth. Also note the increased importance of capital deepening, especially when net output data are used. In that case, it accounts for more than half of overall LP growth. However, our main results regarding the differential LP growth and TFP growth performance of more ICT intensive versus less ICT intensive industries are not only confirmed, but they are strengthened. Both gross and net output based estimates show a period to period increase in TFP growth of more ICT intensive industries, in contrast to the estimates for less ICT intensive industries, with the positive TFP growth differential in favour of more ICT intensive industries being larger than before. Moreover, the pure productivity effects for more ICT intensive industries are now appreciably larger (see Table 5).

6. SUMMARY AND CONCLUDING COMMENTS

This study has provided some new insights into the importance of the various proximate sources of per capita output growth, including LP growth, TFP growth and their sub-components, in more ICT intensive versus less ICT intensive industries in NZ over the 1988-2003 period.

Our key findings can be summarized as follows. There are important differences and distinct patterns in the growth contributions of more ICT intensive versus less ICT intensive industries, supporting our view that the distinction between the two types of industries is useful in explaining economic growth in NZ. Irrespective of whether gross or net output data are used, TFP growth seems to have increased steadily over time, but only in more ICT intensive industries. Until recently, it has been mostly due to structural change effects, not pure (within-industry) productivity gains, although the results for the latest period analysed indicate that this might be changing. LP growth seems to have accelerated later than suggested by Engelbrecht and Xayavong (2006), i.e. only from the late 1990s and not from the early 1990s onwards. Other findings, like those concerning capital shallowness, are more tentative due to data quality problems.

NZ seems to be one of the few countries so far to show positive productivity impacts from ICT use when industry level data are employed. However, our findings are only suggestive, not conclusive. We have to await future studies to determine whether the ICT productivity impacts observed for the period 1999 onwards can be sustained over the full business cycle, or whether they are just the usual pro-cyclical effects that will abate over time. It has also long been recognized that sustained productivity gains due to ICT depend, to a large extent, on a myriad of complementary organisational innovations, investments in various forms of ‘intangible’ capital, and many of the factors affecting firm behaviour in general (Brynjolfsson and Hitt, 2000; OECD, 2004). Without these, higher ICT investment rates will not lift productivity and economic growth.

We end with a call for improved data. Because of data weaknesses, our findings, like those of similar studies (see Ark *et al.*, 2002), might be greatly influenced by measurement issues, for example with respect to service industry outputs. However, the call for improved data is especially urgent in the NZ case. The underlying industry database should be improved in many ways, not least by making hours worked data as well as physical (including ICT) capital and human capital data available at an industry level that would allow a finer separation of more ICT intensive from less ICT intensive industries and by providing data of sufficient quality to meaningfully address the unresolved issue of capital shallowness.

Acknowledgements

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Table 1: Gross Output Based Labour Productivity Growth Rates

		Annual Growth Rate (%)				Acceleration		Is the industry more or less ICT intensive?*		
		1988-92	1992-99	1999-03	1988-03	1992-99 less 1988-92	1999-03 less 1992-99	This study	Stiroh (2002a)	Ark et al. (2002)
1	Agriculture	2.98	2.76	-3.83	1.57	-0.21	-6.60	No	No	No
2	Fishing	9.52	-0.90	-5.39	1.08	-10.42	-4.49	No	No	No
3	Forestry and Logging	8.39	-3.76	5.56	2.77	-12.15	9.32	No	No	No
4	Mining and Quarrying	-1.75	5.07	0.89	2.29	6.83	-4.19	No	No	No
5	Food, Beverage and Tobacco	3.57	2.62	2.06	3.08	-0.95	-0.56	No	No/Yes	No
6	Textiles and Apparel	1.43	2.94	0.69	2.27	1.51	-2.24	No	No/Yes	No/Yes
7	Wood and Paper Products	3.06	1.82	2.20	1.57	-1.24	0.38	No	No	No
8	Printing, Publishing and Recorded Media	-2.58	-0.39	0.40	-0.55	2.20	0.79	Yes	Yes	Yes
9	Petroleum, Chemical, Plastics and Rubber	7.28	3.20	3.76	4.15	-4.08	0.56	No	No	No
10	Non-Metallic Mineral Products	2.73	-0.38	4.53	2.34	-3.11	4.91	No	No	No
11	Metal Product	2.21	0.02	5.37	1.99	-2.19	5.35	No	No	No
12	Machinery and Equipment Manufacturing	-0.48	0.20	2.98	1.41	0.68	2.78	Yes	Yes	Yes
13	Furniture and Other Manufacturing	-2.13	-0.63	2.81	-0.22	1.50	3.44	No	No/Yes	No/Yes
14	Electricity, Gas and Water Supply	9.63	12.00	11.13	9.82	2.38	-0.87	No	No	No
15	Construction	-2.68	-2.49	0.34	-1.06	0.19	2.82	No	No	No
16	Wholesale Trade	0.00	-0.41	5.17	1.01	-0.40	5.58	Yes	Yes	Yes
17	Retail Trade (including motor vehicle repairs)	0.24	0.57	2.17	0.88	0.33	1.60	Yes	Yes	Yes
18	Accommodation, Cafes and Restaurants	-6.89	-3.70	-1.76	-3.97	3.19	1.94	No	No	No
19	Transport and Storage	4.99	5.03	4.51	4.36	0.04	-0.52	Yes	No/Yes	No
20	Communication Services	17.14	11.99	10.48	13.15	-5.15	-1.50	Yes	Yes	Yes
21	Finance, Insurance	3.69	5.32	4.58	4.20	1.62	-0.73	Yes	Yes	Yes
22	Property Services	-3.08	0.14	2.13	-0.42	3.22	1.99	No	No	No
23	Ownership of Owner Occupied Dwellings	-1.98	-2.82	-2.58	-2.95	-0.84	0.24	Yes	Yes	Yes
24	Business Services	-2.86	-1.38	-0.46	-1.58	1.48	0.92	Yes	Yes	No/Yes
25	Government	0.95	1.37	-0.13	1.48	0.41	-1.50	Yes	n.a.	No
26	Education	1.42	0.70	2.35	1.11	-0.72	1.64	Yes	Yes	No
27	Health and Community Services	4.00	3.59	2.12	2.73	-0.41	-1.47	Yes	Yes	No
28	Cultural and Recreational Services	-0.92	-2.47	-0.16	-1.13	-1.55	2.31	Yes	n.a.	No
29	Personal and Other Community Services	-2.30	1.86	-1.17	-0.08	4.16	-3.03	Yes	n.a.	No
	Mean, all industries	1.92	1.44	2.09	1.77	-0.47	0.65			
	Mean, less ICT intensive industries	2.28	1.25	2.03	1.82	-1.04	0.78	Industry Classification A		
	Mean, more ICT intensive industries	1.52	1.65	2.16	1.72	0.13	0.51			
	Mean, less ICT intensive industries	2.67	1.14	2.57	1.97	-1.53	1.43	Industry Classification B		
	Mean, more ICT intensive industries	1.39	1.66	1.76	1.63	0.27	0.10			
	Output Share Weighted Mean, all industries	1.59	1.48	2.14	1.69	-0.10	0.65			
	Mean, less ICT intensive industries	0.84	0.74	0.79	0.83	-0.11	0.05	Industry Classification A		
	Mean, more ICT intensive industries	0.74	0.75	1.35	0.85	0.00	0.60			
	Mean, less ICT intensive industries	0.65	0.54	0.99	0.71	-0.11	0.45	Industry Classification B		
	Mean, more ICT intensive industries	0.93	0.94	1.15	0.97	0.01	0.20			

Note: Industry Classification B includes industries 1, 6 and 13 in the more ICT intensive category.

Table 2: Net Output Based Labour Productivity Growth Rates

		Annual Growth Rate (%)						Is the industry more ICT intensive?
		1988-92	1992-99	1999-03	1988-03	1992-99 less 1988-92	1999-03 less 1992-99	
1	Agriculture	2.17	2.71	-1.44	1.85	0.54	-4.15	No
2	Fishing	8.29	-1.28	-2.55	1.53	-9.57	-1.27	No
3	Forestry and Logging	12.73	-4.58	0.15	1.86	-17.31	4.72	No
4	Mining and Quarrying	2.69	3.53	-1.28	2.07	0.84	-4.81	No
5	Food, Beverage and Tobacco	1.44	1.52	0.43	1.22	0.09	-1.09	No
6	Textiles and Apparel	3.20	3.93	1.54	2.69	0.73	-2.39	No
7	Wood and Paper Products	3.75	0.59	2.47	1.87	-3.16	1.88	No
8	Printing, Publishing and Recorded Media	-1.76	0.19	-1.11	-0.55	1.95	-1.30	Yes
9	Petroleum, Chemical, Plastics and Rubber	5.26	1.93	2.63	3.08	-3.33	0.70	No
10	Non-Metallic Mineral Products	5.12	0.36	2.81	2.93	-4.76	2.45	No
11	Metal Product	3.62	1.82	3.13	2.73	-1.80	1.31	No
12	Machinery and Equipment Manufacturing	1.15	0.72	2.25	1.51	-0.43	1.53	Yes
13	Furniture and Other Manufacturing	-3.18	0.35	2.43	0.26	3.53	2.08	No
14	Electricity, Gas and Water Supply	9.50	9.05	7.91	7.66	-0.45	-1.13	No
15	Construction	-1.81	-1.53	-0.70	-0.44	0.28	0.82	No
16	Wholesale Trade	1.00	-0.45	3.93	1.40	-1.45	4.38	Yes
17	Retail Trade (including motor vehicle repairs)	-0.30	0.99	1.63	0.92	1.29	0.64	Yes
18	Accommodation, Cafes and Restaurants	-5.31	-1.56	-1.50	-2.09	3.75	0.06	No
19	Transport and Storage	5.56	3.76	2.14	3.20	-1.80	-1.62	Yes
20	Communication Services	14.79	10.03	8.31	11.02	-4.76	-1.72	Yes
21	Finance, Insurance	2.25	4.73	4.65	3.82	2.48	-0.09	Yes
22	Property Services	-2.97	-0.50	2.57	-0.50	2.46	3.07	No
23	Ownership of Owner Occupied Dwellings	-0.99	-2.43	-2.84	-2.70	-1.44	-0.41	Yes
24	Business Services	-3.95	-1.73	-2.24	-2.24	2.22	-0.51	Yes
25	Government	0.81	1.72	0.94	1.36	0.91	-0.78	Yes
26	Education	-0.99	-0.78	1.43	-0.25	0.21	2.21	Yes
27	Health and Community Services	1.88	2.32	1.52	1.72	0.43	-0.80	Yes
28	Cultural and Recreational Services	-3.29	0.52	0.25	-0.33	3.81	-0.27	Yes
29	Personal and Other Community Services	-1.61	2.54	-0.33	0.78	4.15	-2.87	Yes
	Mean, all industries	2.04	1.33	1.35	1.60	-0.71	0.02	
	Mean, less ICT intensive industries	2.97	1.09	1.24	1.78	-1.88	0.15	Industry
	Mean, more ICT intensive industries	1.04	1.58	1.47	1.40	0.54	-0.12	Classif. A
	Mean, less ICT intensive industries	3.53	0.78	1.34	1.83	-2.75	0.56	Industry
	Mean, more ICT intensive industries	0.99	1.71	1.36	1.44	0.73	-0.36	Classif. B
	Value Added Share Weighted Mean, all industries	1.44	1.21	1.25	1.29	-0.23	0.04	
	Mean, less ICT intensive industries	0.68	0.50	0.41	0.56	-0.18	-0.09	Industry
	Mean, more ICT intensive industries	0.76	0.71	0.84	0.73	-0.05	0.13	Classif. A
	Mean, less ICT intensive industries	0.54	0.30	0.47	0.43	-0.23	0.16	Industry
	Mean, more ICT ntensive industries	0.91	0.91	0.78	0.86	0.00	-0.13	Classif. B

Note: See Table 1.

Table 3: Proximate Sources of Growth in Per Capita Output (Gross Output Based Approach, Industry Classification A)

	1988-92	1992-99	1999-03	1988-03	1992-99 less 1988-92	1999-03 less 1992-99
I. Growth of Per Capita Output	**-2.01**	**1.60**	**2.82**	**1.38**	**3.60**	**1.23**
I.1 Labour Utilisation	**-3.60**	**0.11**	**0.69**	**-0.30**	**3.71**	**0.57**
I.2 Labour Productivity	**1.59**	**1.48**	**2.14**	**1.69**	**-0.10**	**0.65**
less ICT intensive industries	*0.84*	*0.74*	*0.79*	*0.83*	*-0.11*	*0.05*
more ICT intensive industries	*0.74*	*0.75*	*1.35*	*0.85*	*0.00*	*0.60*
Contribution from:						
I.2.1 Capital Deepening	**0.68**	**0.13**	**0.21**	**0.23**	**-0.55**	**0.08**
less ICT intensive industries	*0.41*	*0.14*	*0.17*	*0.18*	*-0.27*	*0.02*
more ICT intensive industries	*0.27*	*-0.01*	*0.05*	*0.05*	*-0.28*	*0.05*
I.2.2 Labour Quality	**0.16**	**0.14**	**0.13**	**0.14**	**-0.02**	**-0.01**
less ICT-intensive industries	*0.08*	*0.02*	*-0.03*	*0.02*	*-0.06*	*-0.04*
more ICT-intensive industries	*0.09*	*0.12*	*0.16*	*0.12*	*0.04*	*0.04*
I.2.3 Intermediate Input	**1.01**	**0.90**	**0.86**	**0.79**	**-0.11**	**-0.04**
less ICT intensive industries	*0.60*	*0.69*	*0.64*	*0.62*	*0.09*	*-0.05*
more ICT intensive industries	*0.41*	*0.21*	*0.22*	*0.17*	*-0.20*	*0.01*
I.2.4 Total Factor Productivity	**-0.26**	**0.31**	**0.93**	**0.53**	**0.58**	**0.62**
less ICT intensive industries	*-0.27*	*-0.16*	*-0.06*	*-0.03*	*0.12*	*0.09*
more ICT intensive industries	*0.01*	*0.47*	*1.00*	*0.57*	*0.46*	*0.53*
Contribution from:						
I.2.4. 1 Pure Productivity Effect	**-0.07**	**0.11**	**0.28**	**0.12**	**0.18**	**0.17**
less ICT intensive industries	*-0.07*	*0.02*	*0.00*	*0.00*	*0.09*	*-0.02*
more ICT intensive industries	*0.00*	*0.08*	*0.28*	*0.12*	*0.08*	*0.19*
I.2.4.2 Baumol Effect	**0.01**	**-0.01**	**-0.02**	**-0.01**	**-0.02**	**-0.01**
less ICT intensive industries	*0.01*	*0.00*	*0.00*	*0.00*	*-0.01*	*0.00*
more ICT intensive industries	*0.00*	*0.00*	*-0.02*	*-0.01*	*0.00*	*-0.02*
I.2.4.3 Denison Effect	**-0.18**	**0.20**	**0.65**	**0.41**	**0.37**	**0.46**
less ICT intensive industries	*-0.19*	*-0.18*	*-0.06*	*-0.03*	*0.00*	*0.12*
more ICT intensive industries	*0.01*	*0.38*	*0.72*	*0.44*	*0.37*	*0.34*
I.2.4.4 Fixed Weighted Drift Term	**-0.03**	**0.02**	**0.02**	**0.01**	**0.04**	**0.00**
less ICT intensive industries	*-0.03*	*0.00*	*0.00*	*0.00*	*0.03*	*0.00*
more ICT intensive industries	*0.00*	*0.01*	*0.02*	*0.01*	*0.01*	*0.01*

Table 4: Proximate Sources of Growth in Per Capita Output (Net Output Based Approach, Industry Classification A)

	1988-92	1992-99	1999-03	1988-03	1992-99 less 1988-92	1999-03 less 1992-99
I. Growth of Per Capita Output	**-1.52**	**1.46**	**2.07**	**1.21**	**2.98**	**0.61**
I.1 Labour Utilisation	**-2.97**	**0.25**	**0.82**	**-0.08**	**3.21**	**0.57**
I.2 Labour Productivity	**1.44**	**1.21**	**1.25**	**1.29**	**-0.23**	**0.04**
less ICT intensive industries	*0.68*	*0.50*	*0.41*	*0.56*	*-0.18*	*-0.09*
more ICT intensive industries	*0.76*	*0.71*	*0.84*	*0.73*	*-0.05*	*0.13*
Contribution from:						
I.2.1 Capital Deepening	**1.37**	**0.25**	**0.40**	**0.43**	**-1.12**	**0.15**
less ICT intensive industries	*0.83*	*0.27*	*0.31*	*0.34*	*-0.56*	*0.04*
more ICT intensive industries	*0.54*	*-0.02*	*0.09*	*0.09*	*-0.56*	*0.11*
I.2.2 Labour Quality	**0.33**	**0.27**	**0.25**	**0.27**	**-0.06**	**-0.01**
less ICT intensive industries	*0.15*	*0.03*	*-0.05*	*0.05*	*-0.12*	*-0.08*
more ICT intensive industries	*0.17*	*0.23*	*0.31*	*0.22*	*0.06*	*0.07*
I.2.3 Total Factor Productivity	**-0.25**	**0.70**	**0.60**	**0.59**	**0.95**	**-0.10**
less ICT intensive industries	*-0.32*	*0.11*	*0.01*	*0.09*	*0.43*	*-0.10*
more ICT intensive industries	*0.07*	*0.58*	*0.59*	*0.49*	*0.51*	*0.01*
Contribution from:						
I.2.3.1 Pure Productivity Effect	**-0.21**	**0.27**	**0.21**	**0.20**	**0.48**	**-0.05**
less ICT intensive industries	*-0.22*	*0.04*	*0.00*	*0.03*	*0.26*	*-0.04*
more ICT intensive industries	*0.01*	*0.22*	*0.21*	*0.17*	*0.21*	*-0.01*
I.2.3.2 Baumol Effect	**0.03**	**-0.03**	**-0.04**	**-0.02**	**-0.06**	**-0.01**
less ICT intensive industries	*0.02*	*-0.01*	*0.00*	*0.00*	*-0.03*	*0.01*
more ICT intensive industries	*0.01*	*-0.02*	*-0.04*	*-0.02*	*-0.03*	*-0.02*
I.2.3.3 Denison Effect	**-0.02**	**0.45**	**0.41**	**0.41**	**0.47**	**-0.04**
less ICT intensive industries	*-0.10*	*0.08*	*0.01*	*0.07*	*0.18*	*-0.07*
more ICT intensive industries	*0.08*	*0.37*	*0.40*	*0.34*	*0.28*	*0.03*
I.2.3.4 Fixed Weighted Drift Term	**-0.05**	**0.02**	**0.02**	**0.00**	**0.06**	**0.00**
less ICT intensive industries	*-0.02*	*0.00*	*0.00*	*0.00*	*0.02*	*0.00*
more ICT intensive industries	*-0.03*	*0.02*	*0.02*	*0.01*	*0.05*	*0.00*

Table 5: Proximate Sources of Growth in Per Capita Output Based on 1999-2001 Data.

	Gross output, Industry Classific. A	Gross output, Industry Classific. B	Net output, Industry Classific. A	Net output, Industry Classific. B
I. Growth of Income Per Capita	**3.05**	**3.05**	**1.87**	**1.87**
I.1 Labour Utilisation	**-0.39**	**-0.39**	**-0.22**	**-0.22**
I.2 Labour Productivity	**3.44**	**3.44**	**2.09**	**2.09**
less ICT-intensive industries	*1.39*	*1.63*	*0.81*	*0.79*
more ICT-intensive industries	*2.05*	*1.81*	*1.28*	*1.30*
Contribution from:				
I.2.1 Capital Deepening	**0.55**	**0.55**	**1.09**	**1.09**
less ICT-intensive industries	*0.38*	*0.38*	*0.75*	*0.75*
more ICT-intensive industries	*0.17*	*0.17*	*0.35*	*0.34*
I.2.2 Labour Quality	**0.15**	**0.15**	**0.31**	**0.31**
less ICT-intensive industries	*-0.05*	*0.01*	*-0.10*	*0.02*
more ICT-intensive industries	*0.20*	*0.14*	*0.41*	*0.29*
I.2.3 Intermediate Input	**1.35**	**1.35**		
less ICT-intensive industries	*1.12*	*1.12*		
more ICT-intensive industries	*0.23*	*0.23*		
I.2.4 Total Factor Productivity	**1.40**	**1.40**	**0.69**	**0.69**
less ICT-intensive industries	*-0.15*	*0.08*	*-0.07*	*-0.10*
more ICT-intensive industries	*1.54*	*1.32*	*0.76*	*0.79*
Contribution from:				
I.2.4.1 Pure Productivity Effect	**0.65**	**0.52**	**-0.02**	**-0.01**
less ICT-intensive industries	*0.01*	*0.01*	*-0.38*	*-0.40*
more ICT-intensive industries	*0.64*	*0.52*	*0.36*	*0.38*
I.2.42 Baumol Effect	**-0.05**	**-0.08**	**-0.05**	**-0.06**
less ICT-intensive industries	*0.01*	*0.00*	*0.04*	*0.02*
more ICT-intensive industries	*-0.06*	*-0.08*	*-0.09*	*-0.09*
I.2.4.3 Denison Effect	**0.71**	**0.87**	**0.77**	**0.69**
less ICT-intensive industries	*-0.16*	*0.07*	*0.35*	*0.26*
more ICT-intensive industries	*0.88*	*0.80*	*0.42*	*0.43*
I.2.4.4 Fixed Weighted Drifted Terms	**0.09**	**0.08**	**-0.01**	**0.07**
less ICT-intensive industries	*0.00*	*0.00*	*-0.07*	*0.02*
more ICT-intensive industries	*0.09*	*0.08*	0.06	0.06

APPENDIX 1: THE INDUSTRY-LEVEL LABOUR PRODUCTIVITY ACCOUNTING EQUATION

Industry *i*'s Cobb-Douglass Production Function is:

$$Y_{i,t} = K_{i,t}^{\alpha_{i,t}} L_{i,t}^{\beta_{i,t}} M_{i,t}^{\gamma_{i,t}} A_{i,t} \tag{A.1}$$

Dividing both sides of equation (A.1) by E_t and taking logs yields:

$$\ln(Y/E)_{i,t} = \alpha_{i,t} \ln K_{i,t} + \beta_{i,t} \ln L_{i,t} + \gamma_{i,t} \ln M_{i,t} + \ln A_{i,t} - \ln E_{i,t} \tag{A.2}$$

Adding and subtracting $\alpha_{i,t} \ln E_{i,t}, \beta_{i,t} \ln E_{i,t}, \gamma_{i,t} \ln E_{i,t}$ to/from equation (A.2) yields:

$$\begin{aligned}\ln(Y/E)_{i,t} = {} & \alpha_{i,t} \ln(K/E)_{i,t} + \beta_{i,t} \ln(L/E)_{i,t} + \gamma_{i,t} \ln(M/E)_{i,t} + \ln A_{i,t} \\ & + (\alpha_{i,t} + \beta_{i,t} + \gamma_{i,t}) \ln E_{i,t} - \ln E_{i,t}\end{aligned} \tag{A.3}$$

Growth accounting assumes a constant returns to scale technology. This implies $(\alpha_{i,t} + \beta_{i,t} + \gamma_{i,t}) = 1$. Therefore, equation (A.3) can be written as:

$$\ln(Y/E)_{i,t} = \alpha_{i,t} \ln(K/E)_{i,t} + \beta_{i,t} \ln(L/E)_{i,t} + \gamma_{i,t} \ln(M/E)_{i,t} + \ln A_{i,t} \tag{A.4}$$

Applying Domar's (1961) weighting scheme to equation (A.4), per capita output growth at aggregate and industry levels can be expressed as:

$$\begin{aligned}\Delta \ln(Y/E)_t = \sum_i \bar{\sigma}_{i,t} \Delta \ln(Y/E)_{i,t} = {} & \sum_i \bar{\sigma}_{i,t} \bar{\alpha}_{i,t} \Delta \ln(K/E)_{i,t} \\ & + \sum_i \bar{\sigma}_{i,t} \bar{\beta}_{i,t} \Delta \ln(L/E)_{i,t} \\ & + \sum_i \bar{\sigma}_{i,t} \bar{\gamma}_{i,t} \Delta \ln(M/E)_{i,t} \\ & + \sum_i \bar{\sigma}_{i,t} \Delta \ln(A)_{i,t}\end{aligned} \tag{A.5}$$

This is our equation 2.

APPENDIX 2:
Table A1:
Definition of ICT intensive industries: Comparison with Ark et al. (2002) and Stiroh (2002).

ISIC	Industry classification used in Ark et al. (2002), Appendix A		Industry classification used in Engelbrecht & Xayavong (2006)	Is the industry more or less ICT intensive? Engelbrecht & Xayavong (2006)	Ark et al. (2002)	Stiroh (2002)
01-05	AGRICULTURE, HUNTING, FORESTRY AND FISHING	1	Agriculture	No	No	No
		2	Fishing	No		
		3	Forestry and Logging	No		
01-05	MINING AND QUARRYING	4	Mining and Quarrying	No	No	No
15-16	FOOD PRODUCTS, BEVERAGES AND TOBACCO	5	Food, Beverage and Tobacco	No	No	No/Yes
17	TEXTILES	6	Textiles and Apparel	No	No	No
18	WEARING APPAREL, DRESSING AND DYING OF FUR (c)				Yes	Yes
19	LEATHER, LEATHER PRODUCTS AND FOOTWEAR				No	No
20	WOOD AND PRODUCTS OF WOOD AND CORK	7	Wood and Paper Products	No	No	No
21	PULP, PAPER, PAPER PRODUCTS				No	No
22	PRINTING & PUBLISHING (c)	8	Printing, Publishing and Recorded Media	Yes	Yes	Yes
		9	Petroleum, Chemical, Plastics and Rubber			
23	COKE, REFINED PETROLEUM PRODUCTS AND NUCLEAR FUEL			No	No	No
24	CHEMICALS AND CHEMICAL PRODUCTS				No	No
25	RUBBER AND PLASTICS PRODUCTS				No	No
26	OTHER NON-METALLIC MINERAL PRODUCTS	10	Non-Metallic Mineral Products	No	No	No
27	BASIC METALS	11	Metal Product	No	No	No
28	FABRICATED METAL PRODUCTS, except machinery and equipment				No	No
		12	Machinery and Equipment Manufacturing			
29	MACHINERY AND EQUIPMENT, NEC (c)			Yes	Yes	Yes
30	OFFICE, ACCOUNTING AND COMPUTING MACHINERY (a)				Yes	Yes
31	ELECTRICAL MACHINERY AND APPARATUS, NEC (c)				Yes	Yes
313	Fiber optics (a)				Yes	Yes
31-313	Electrical machinery and apparatus, excl. fiber optics (b)				Yes	Yes
32	RADIO, TELEVISION AND COMMUNICATION EQUIPMENT (a/p)				Yes	Yes
33	MEDICAL, PRECISION AND OPTICAL INSTRUMENTS (c)				Yes	Yes
331	Medical, measuring and industrial control instruments (a)				Yes	Yes
33-331	Medical, precision and optical instruments excl. other instruments (b)				Yes	Yes
34	MOTOR VEHICLES, TRAILERS AND SEMI-TRAILERS				No	No
35	OTHER TRANSPORT EQUIPMENT				Yes	Yes
351	Building and repairing of ships and boats (c)				Yes	Yes
353	Aircraft and spacecraft (c)				Yes	Yes
352+359	Railroad equipment and other transport equipment, nec (c)				Yes	Yes
36-37	MANUFACTURING NEC; RECYCLING (c)	13	Furniture and Other Manufacturing	No	Yes	Yes
40-41	ELECTRICITY, GAS AND WATER SUPPLY	14	Electricity, Gas and Water Supply	No	No	No
45	CONSTRUCTION	15	Construction	No	No	No
51	WHOLESALE TRADE (d)	16	Wholesale Trade	Yes	Yes	Yes
50	REPAIRS	17	Retail Trade (including motor vehicle repairs)	Yes	No	No/Yes
52	RETAIL TRADE (d)				Yes	Yes
55	HOTELS AND RESTAURANTS	18	Accommodation, Cafes and Restaurants	No	No	No
60-63	TRANSPORT AND STORAGE	19	Transport and Storage	Yes	No	No/Yes
64	POST AND TELECOMMUNICATIONS (b)	20	Communication Services	Yes	Yes	Yes
65	FINANCIAL INTERMEDIATION except insurance & pension funding (d)	21	Finance, Insurance	Yes	Yes	Yes
66	INSURANCE & PENSION FUNDING, except compulsory social security (d)				Yes	Yes
67	ACTIVITIES RELATED TO FINANCIAL INTERMEDIATION (d)				Yes	Yes
70	REAL ESTATE ACTIVITIES	22	Property Services	No	No	No
71	RENTING OF MACHINERY AND EQUIPMENT (d)	23	Ownership of Owner Occupied Dwellings	Yes	Yes	Yes
72	COMPUTER AND RELATED ACTIVITIES (b)	24	Business Services	Yes	Yes	Yes
73	RESEARCH AND DEVELOPMENT (d)				Yes	Yes
74	OTHER BUSINESS ACTIVITIES				No/Yes	Yes
741-743	Professional Service (d)				Yes	Yes
749	Other business activities, excl. professional				No	Yes
75	PUBLIC ADMIN AND DEFENCE; COMPULSORY SOCIAL SECURITY	25	Government	Yes	No	na
80	EDUCATION	26	Education	Yes	No	Yes
85	HEALTH AND SOCIAL WORK	27	Health and Community Services	Yes	No	Yes
90-93	OTHER COMMUNITY, SOCIAL AND PERSONAL SERVICES	28	Personal and Other Community Services	Yes	No	na/No/Yes
95	PRIVATE HOUSEHOLDS WITH EMPLOYED PERSONS	29	Cultural and Recreational Services	Yes	No	No
99	EXTRA-TERRITORIAL ORGANIZATIONS AND BODIES				No	No

Notes**:** In the second column, letters in brackets indicate the ICT intensive industries according to Ark et al (2002, Table 2, p.5). Letter (a) represents ICT-producing manufacturing, (b) ICT-producing services, (c) ICT-using manufacturing, and (d) ICT using services. If only part of an industry is ICT-intensive, /p is attached to the letter.

Table A2:
Average Annual Changes and Proportional Changes in Output Shares $(\bar{\sigma}_{i,t})$

		Average Annual Shares (%)				Proportional Changes*		Is the industry more ICT intensive?
		1988-92	1992-99	1999-03	1988-03	1992-99 and 1988-92	1999-03 and 1992-99	
1	Agriculture	5.9	5.8	6.0	5.9	-0.9	3.8	No
2	Fishing	0.4	0.4	0.4	0.4	-0.5	-5.7	No
3	Forestry and Logging	0.9	1.3	1.3	1.2	33.9	1.1	No
4	Mining and Quarrying	1.1	1.1	1.0	1.1	-2.0	-10.8	No
5	Food, Beverage and Tobacco Manufacturing	9.1	9.6	9.6	9.5	6.0	-0.3	No
6	Textiles and Apparel Manufacturing	1.9	1.5	1.1	1.5	-21.6	-27.6	No
7	Wood and Paper Products Manufacturing	2.8	2.8	2.6	2.8	3.0	-10.2	No
8	Printing, Publishing and Recorded Media	1.7	1.6	1.4	1.6	-9.3	-11.5	Yes
9	Petroleum, Chemical, Plastics and Rubber Products Manufacturing	3.0	2.8	2.4	2.8	-4.1	-14.8	No
10	Non-Metallic Mineral Products Manufacturing	0.8	0.7	0.7	0.7	-5.9	-6.1	No
11	Metal Product Manufacturing	2.5	2.4	2.3	2.4	-3.5	-4.6	No
12	Machinery and Equipment Manufacturing	3.6	3.2	2.8	3.2	-11.3	-13.0	Yes
13	Furniture and Other Manufacturing	0.7	0.7	0.7	0.7	0.5	-10.3	No
14	Electricity, Gas and Water Supply	2.9	3.0	3.5	3.1	3.5	13.9	No
15	Construction	7.5	6.5	6.9	6.9	-14.4	6.2	No
16	Wholesale Trade	10.0	9.2	8.8	9.3	-8.4	-4.4	Yes
17	Retail Trade (including motor vehicle repairs)	5.7	5.5	5.1	5.4	-3.2	-6.7	Yes
18	Accommodation, Cafes and Restaurants	2.0	1.9	2.0	2.0	-5.9	3.1	No
19	Transport and Storage	5.0	5.0	4.9	5.0	0.7	-2.1	Yes
20	Communication Services	2.2	2.5	2.6	2.4	11.1	5.0	Yes
21	Finance, Insurance	4.9	4.6	4.5	4.6	-7.4	-1.5	Yes
22	Property Services	3.5	3.9	4.1	3.9	10.6	5.9	No
23	Ownership of Owner Occupied Dwellings	4.6	4.7	4.4	4.5	2.3	-6.5	Yes
24	Business Services	4.6	5.6	6.9	5.8	17.1	22.5	Yes
25	Government	5.1	4.7	4.1	4.5	-8.7	-12.9	Yes
26	Education	2.3	2.5	2.7	2.5	8.4	9.1	Yes
27	Health and Community Services	3.0	3.4	3.8	3.4	11.0	12.6	Yes
28	Cultural and Recreational Services	1.5	1.8	2.0	1.8	16.1	15.9	Yes
29	Personal and Other Community Services	1.0	1.1	1.2	1.1	7.7	15.6	Yes
		100	100	100	100			

Notes:
*The change rate was computed as the difference between the shares of two sub-periods (e.g. 1992-99 and 1988-92) over the average share of the entire period (1988-03), i.e. they measure the proportional changes in industry shares compared to their average shares for the entire 1988-2003 period.

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